Tektronix 465 Oscilloscope – Power Supply Capacitor Replacement

Ron Childress – October 2008

Introduction

The purpose of this document is to help others replace power supply capacitors in vintage Tektronix 465 and similar oscilloscopes. This paper outlines a first-time journey with the trial and tribulations of the process. The story is told in chronological order, which is not necessarily the best project order. A few mistakes were made, but that's part of the learning process.

The Symptom

The 465 scope had been in storage for a couple of years. When it was put back in service, a new symptom appeared, as shown below in Figure 1:

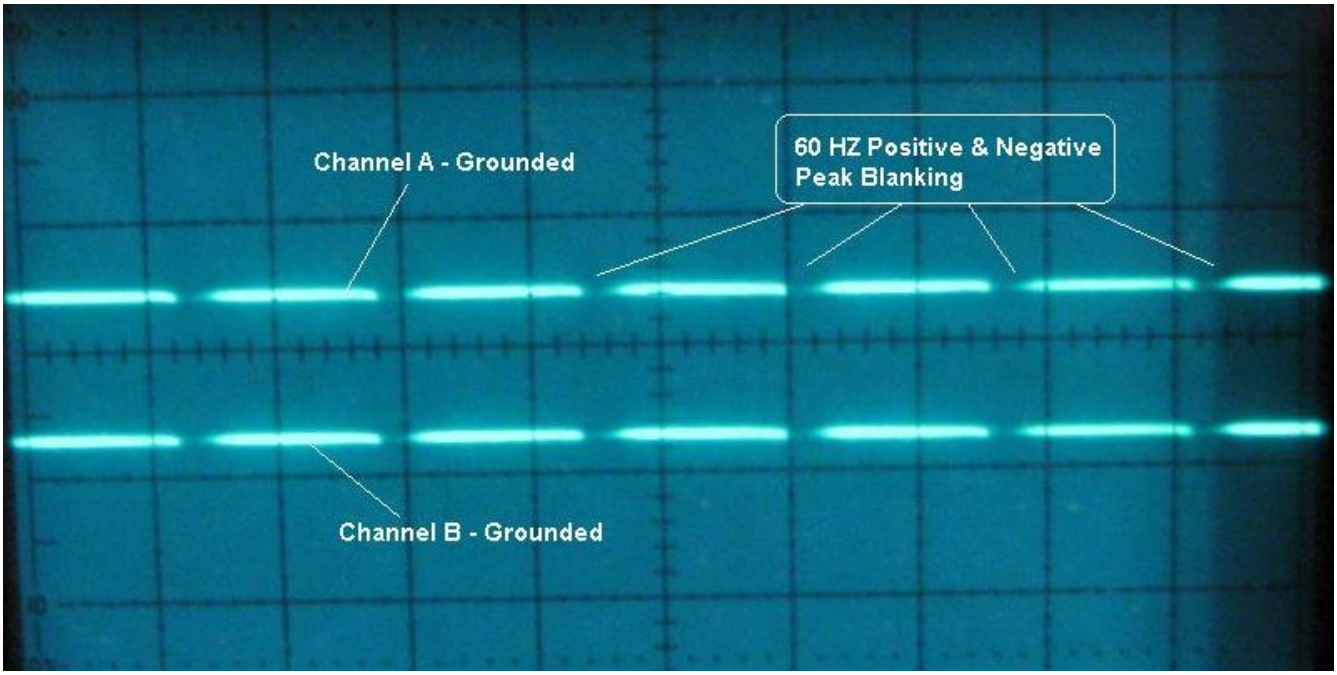

Figure 1: Initial Symptom - 120 HZ Noise appears in Trace A and B

The symptom was isolated with the following settings:

- Set Horizontal sweep to 5 milliseconds per division.
- Set Vertical to Channel to Chop to display both Channel A and B
- Set Channel A and B vertical switches to GND.
- Position each trace vertically, as shown above
- Set Trigger Mode to NORM
- Set Trigger Source to Line to synchronize to 60 HZ.
- Reduce the beam intensity (counter-clockwise) to a bare minimum to see the trace.

Where a continuous trace is expected, blanks occur on the positive and negative peaks of a 60 Hertz cycle. This symptom definitely points to a power supply problem. The question is: where?

The Root Cause

Eventually, the root cause was tracked down to capacitor C1512. This capacitor filters one-half of the +110 VDC power supply from the output of full-wave bridge rectifier C1511, shown in Figure 2. Unfiltered noise at this location propagates to the +110 VDC, +55 VDC and +5 VDC regulated supplies. Noise on the +5 VDC supply causes the blanking symptom shown in Figure 1.

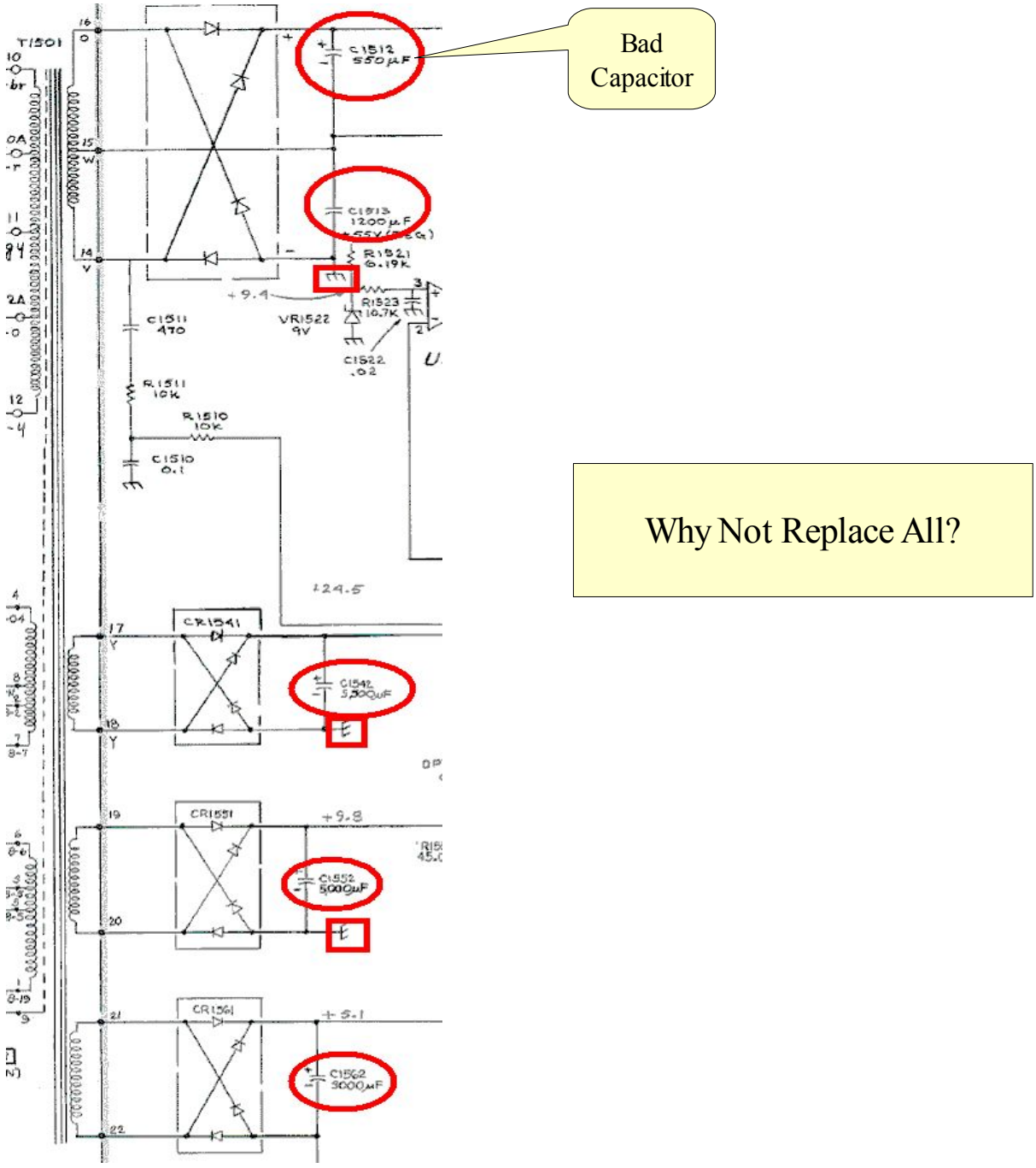

Figure 2: Low Voltage Power Supply

The Purchase

Thinking it was a good idea to replace all of the power supply electrolytic capacitors, extended research revealed obtaining exact capacitor replacements is nearly impossible. Apparently, the last thirty-five years have brought substantial improvements to the manufacturing process.

When restoring vintage tube amplifiers, hard-core enthusiasts cut aluminum capacitor cans and rebuild the internals with newer, smaller sized capacitors. Their goal is to maintain the same look and feel as the original equipment. My goal is simple repair, not vintage restoration.

There are lots of capacitors available and most are smaller in size than their predecessors. Based on quality, prices vary widely. Shockingly, some capacitors cost $40 and up!

Because older Tektronix scopes use linear power supplies, ESR and ripple requirements are not really a concern as compared with newer high frequency switchers. Fortunately, this allows less expensive capacitors to be selected as acceptable replacements. It was decided to upgrade with higher voltage ratings and a bit more capacitance.

Without removing or measuring the original capacitors, an order was placed as shown in Figure 3:

Figure 3: Replacement Capacitor Order Form

Total cost, including $7 UPS shipping, is less than $20. A bargain!

Table 1 gives a comparison of the original versus replacement capacitors purchased. The voltage ratings of all capacitors were kept the same or increased. Not much thought was given to physical dimensions, since newer capacitors are significantly smaller than older capacitors of the same values and voltage ratings.

Part Number	Purpose	Original	Replacement
C1512	+110 VDC Filter Cap	550 uFd, 100V	560 uFd, 160V
C1513	+55 VDC Filter Cap	1200 uFd, 100V	1200 uFd, 160V
C1542	+15 VDC Filter Cap	5500 uFd, 30V	5600 uFd, 35V
C1552	+5 VDC Filter Cap	5000 uFd, 25V	5600 uFd, 35V
C1562	-8 VDC Filter Cap	3000 uFd, 35V	5600 uFd, 35V

Table 1: Original versus Replacement Capacitor Comparison Chart

A few days later, the replacement capacitors arrived, shown in Figure 4. Capacitor numbers are added to this picture for clarity. These capacitors are even smaller than expected. However, the first hint of trouble is the diameter of capacitor C1513 is larger than the original.

Figure 4: Replacement Capacitors

For comparison, the original capacitors are shown below in Figure 5. An important feature to note on the old capacitors is four terminals, instead of two. The outside three terminals are all connected to the negative (-) side of the capacitor. The positive (+) terminal is in the center.

Figure 5: Original Capacitors Removed

Gaining Access

Removing the old capacitors is the toughest part of the entire job. To gain access, removal of *A8 Trigger Circuit Board* is absolutely required. This was discovered the hard way by tearing a printed circuit board trace completely off the board while attempting to remove C1513. This mistake could have been avoided by first moving the A8 board out of the way.

While removing the *A8 Trigger Circuit Board*, it becomes apparent that this vintage scope was hand assembled in a sequential order and all of the components were hand soldered. Fortunately, removing A8 is not as bad as it first appears.

Figure 6 shows the top side of *A8 Trigger Circuit Board*. First, remove the five screws, one nut and one circuit board stand-off, as indicated below. The nut and screw, holding the power switch assembly, must be removed first to reveal a circuit board screw underneath.

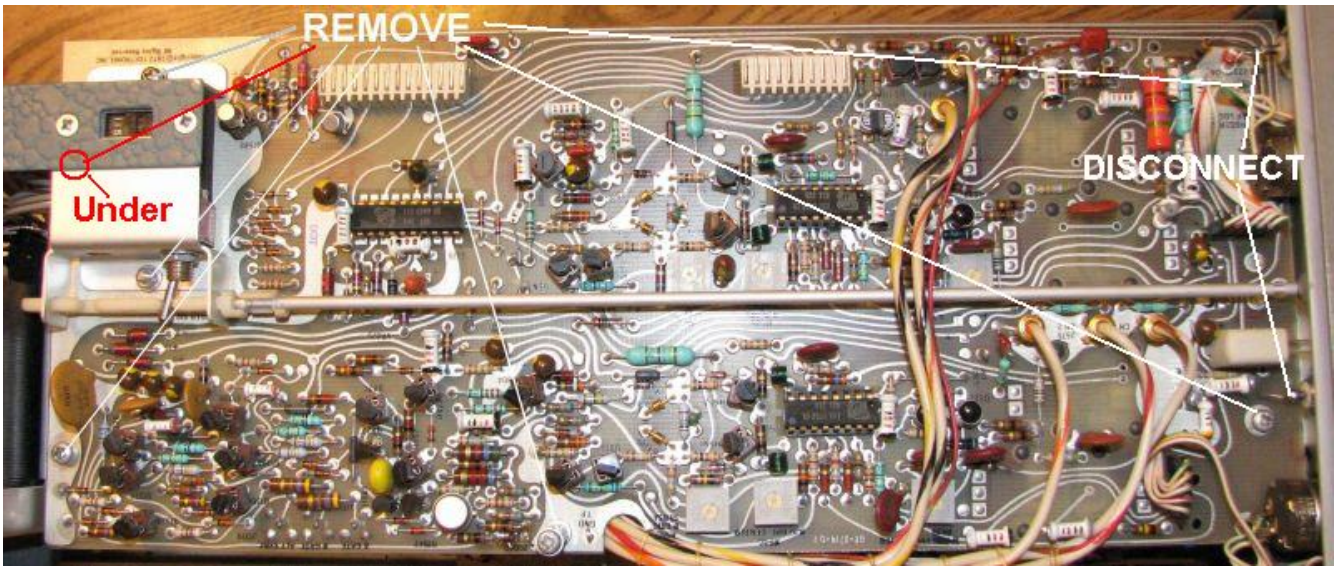

Figure 6: A8 Trigger Circuit Board

Next, unsolder the two external horizontal trigger coax connectors, as shown in Figure 7. Unplug the two ribbon cable connectors and note polarity. These connectors are not keyed, so it is possible to connect them backwards!

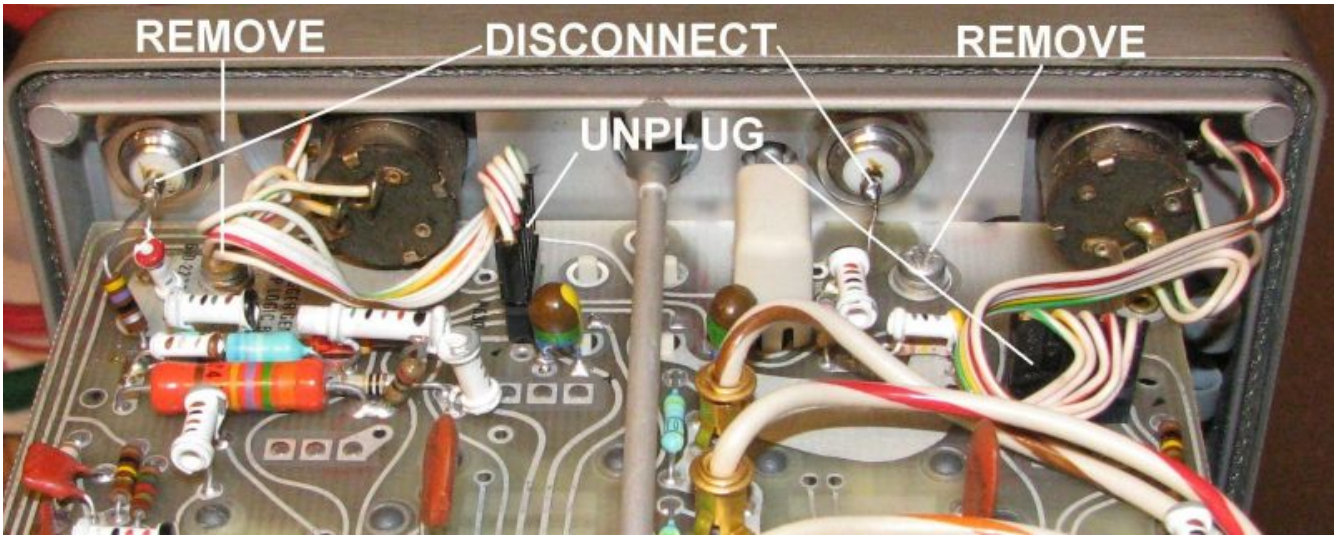

Figure 7: Unsolder A8 coax connections

Next, unsolder the red and black wire from the *A Trigger Hold-Off Switch*, as shown below in Figure 8. Note which wire goes where.

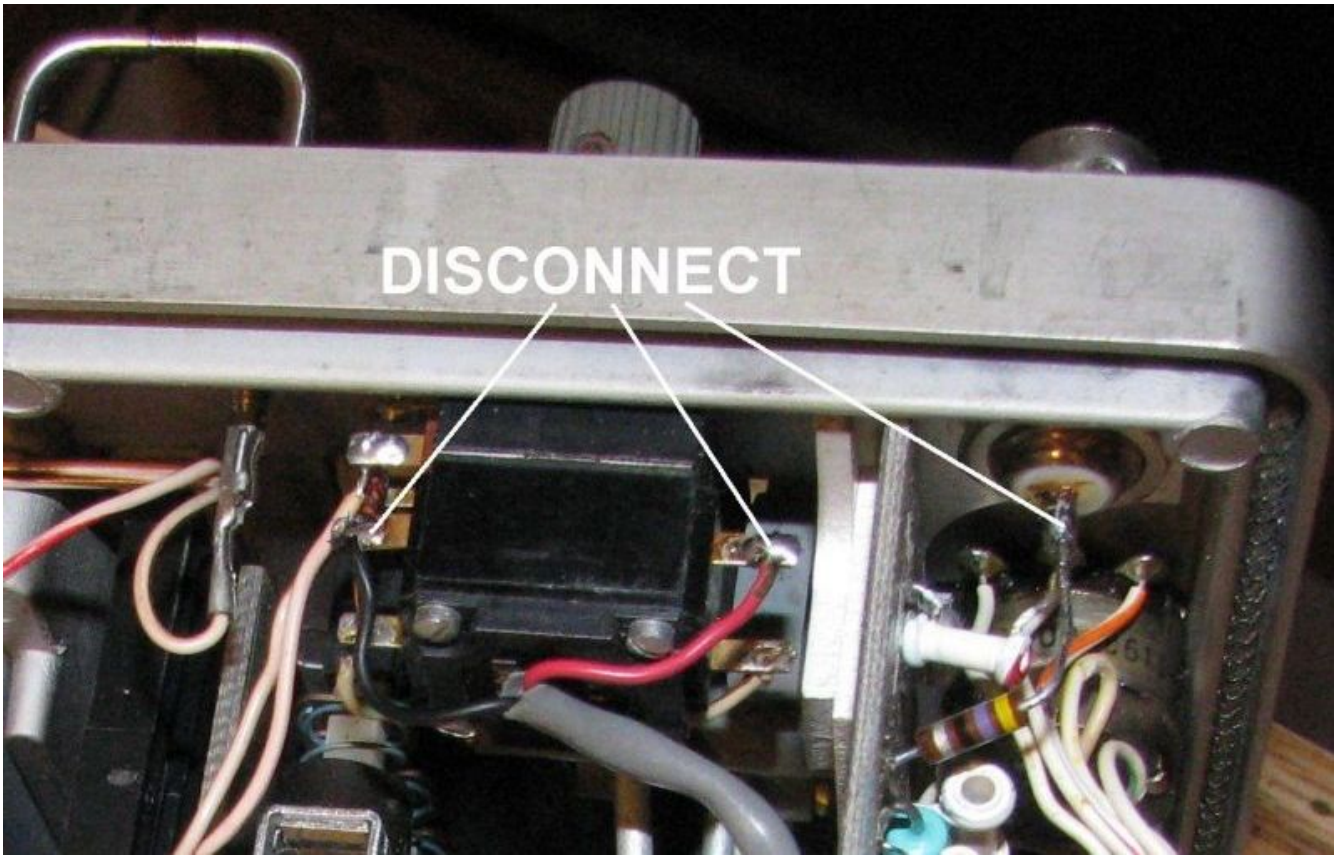

Figure 8: Unsolder red and black wire

Carefully unsnap the power switch rod from the plastic connector and pull the power rod out the front.

Remove the POWER, READY and TRIG clear plastic indicator light pipes from the front panel by pulling straight out.

Remove three wires, located on underneath the A8 board, directly in front of the power supply capacitors. Carefully remove these wires by pulling straight out. Make a note of wire colors and location.

Finally, carefully lift the *A8 Trigger Circuit Board* straight up to unplug the side connectors. Try not to bend any of the pins and straighten them out if you do. Without removing any other wires, the A8 board should swing over to the side and out of the way to gain clear access to the power supply capacitors.

Shown in Figure 9, the *A8 Trigger Circuit Board* is moved out of the way. It's a lot of trouble, but required to replace the power capacitors. Now is a good time to clean those dirty contacts.

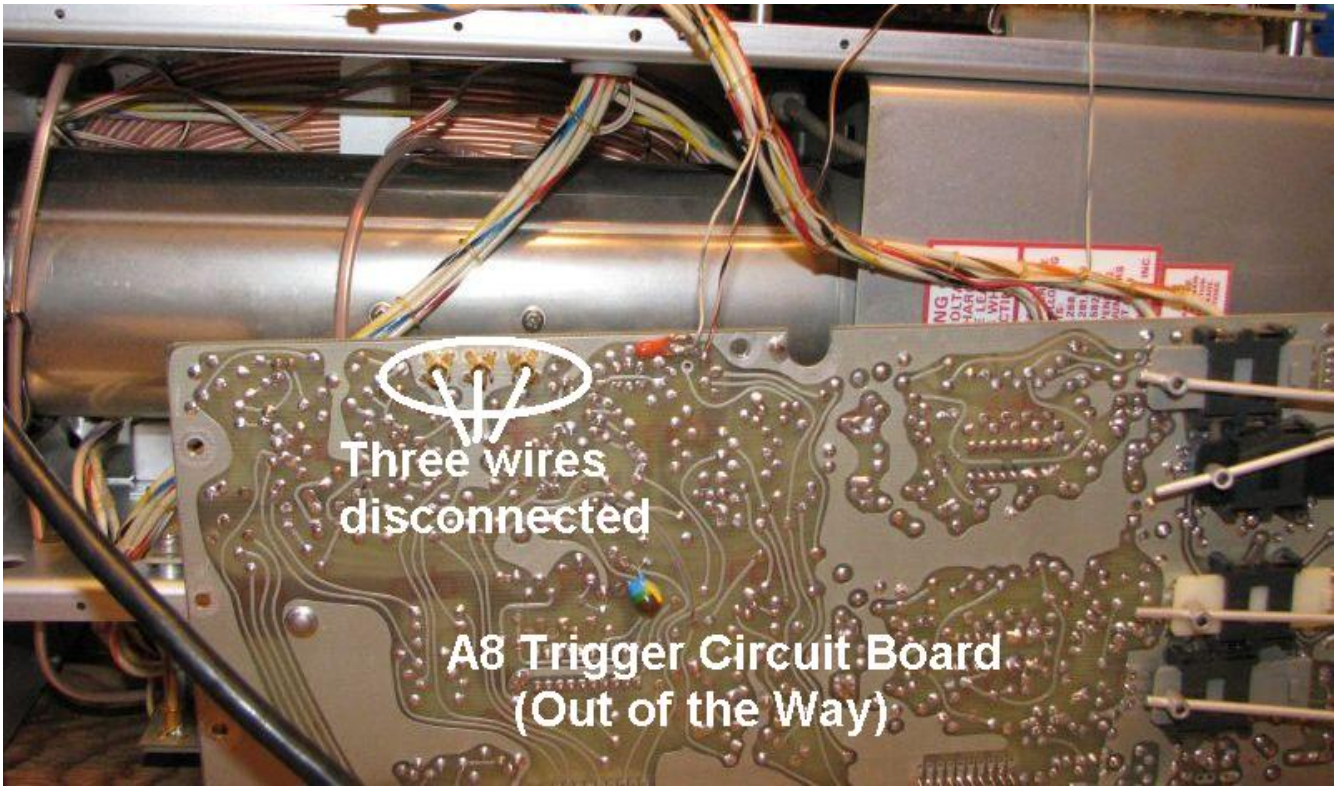

Figure 9: A8 Trigger Circuit Board Moved Out of the Way

Removing Old Capacitors

Removing the old capacitors is the most difficult part of the entire process. Armed with a variable temperature soldering iron, solder removal bulb and solder wick, the removal process began. Figure 10 clearly identifies capacitor locations underneath the circuit board. To remove C1513, one side of the large black resistor must be lifted to gain access to the terminal underneath.

The solder pads must be heated hot enough to melt the solder on both sides of the board. Otherwise, the circuit trace on the capacitor side of the board can be lifted off the board. But, heating the solder pad too hot will cause it to lift off the board on the underside. The removal process is very difficult and requires determination and extra care to minimize circuit board damage.

In retrospect, cutting the capacitors off the board and then removing the tabs may be a better plan. A thin saw blade to reach between the capacitor and board may do the trick. But, the thought of metals filings everywhere seems troublesome.

Anyway, persistence prevails. Eventually, the five power supply capacitors were removed with only minor circuit board damage.

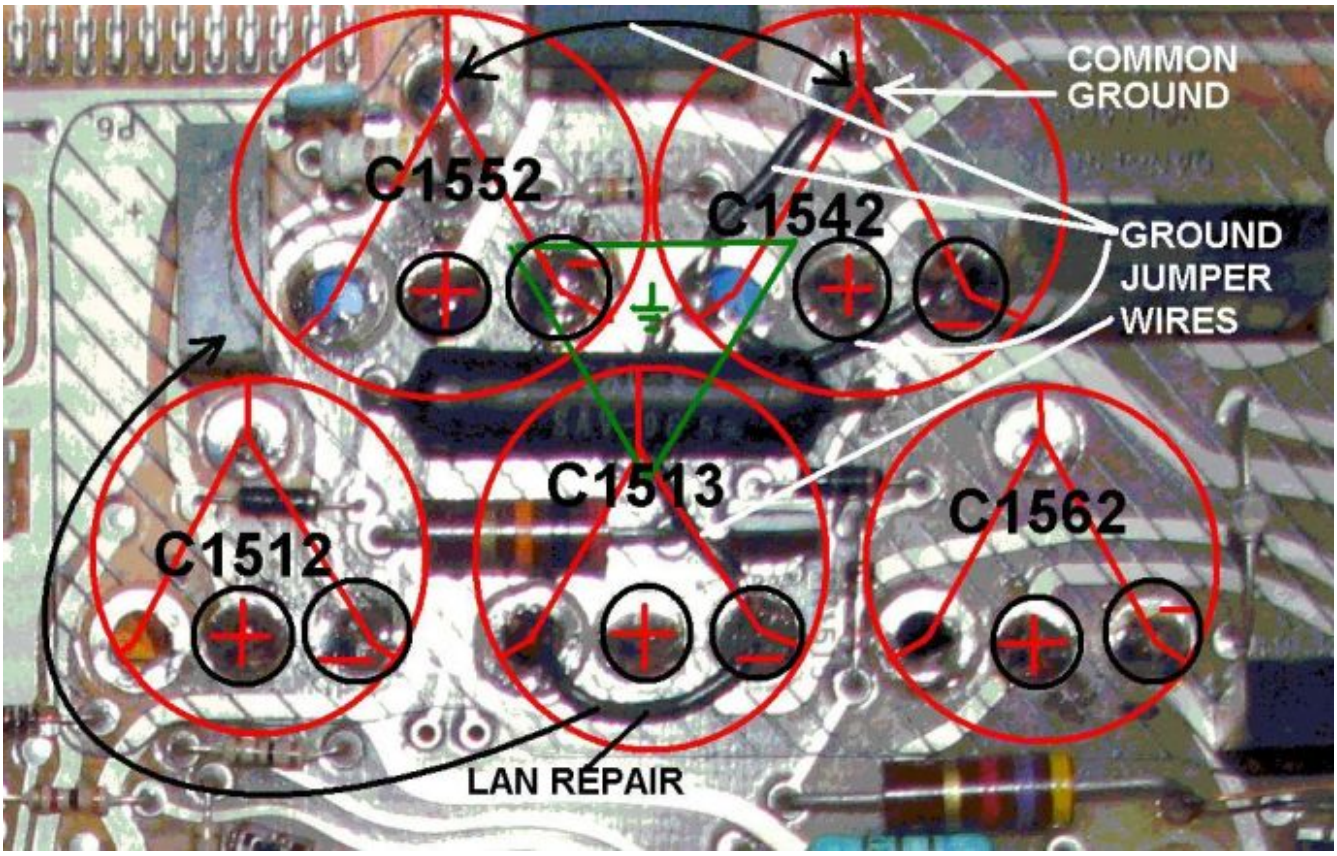

Figure 10: Capacitor Circuit Board Locations

Installing New Capacitors

Before installing the new capacitors, questions must be answered about which circuit board holes to use. Figure 10 shows the positive (+) and negative (-) terminal locations used for each capacitor. Since three ground pads are available per capacitor, other placement options are available.

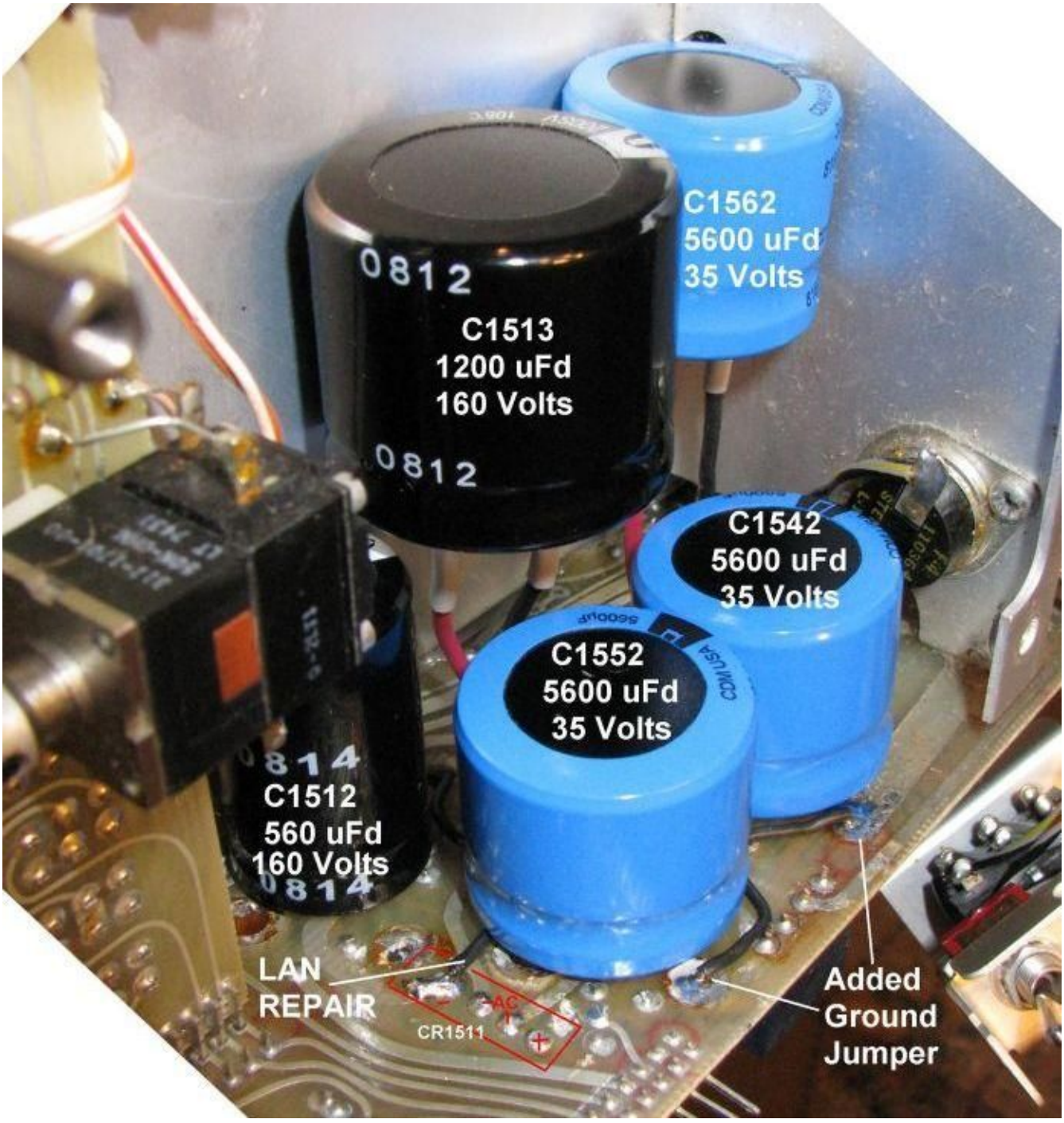

Figure 11: New Capacitors Installed

Capacitor C1512 was installed first. It fit like a glove, as seen in Figure 11.

Next, Capacitor C1513 would not fit directly on the board because the outside diameter was too large. A capacitor with a 100 Volt rating may fit or a capacitor with more height and less diameter. Oh well... Some stiff leads were attached with heat-shrink tubing and the project continued.

Likewise, Capacitor C1562 missed fitting directly on the circuit board by only a couple of millimeters. The original capacitor was 3000 uFds, while this one is 5600 uFds. Live and learn...

Capacitors C1542 and C1552 were installed without incident as shown in Figure 11.

Adding Ground Jumpers

With the old capacitors removed, it is necessary to install ground jumpers, as shown in Figure 12. The original aluminum cans were used to interconnect various grounds to the circuit board. With the aluminum cans removed, these ground connections must be reestablished.

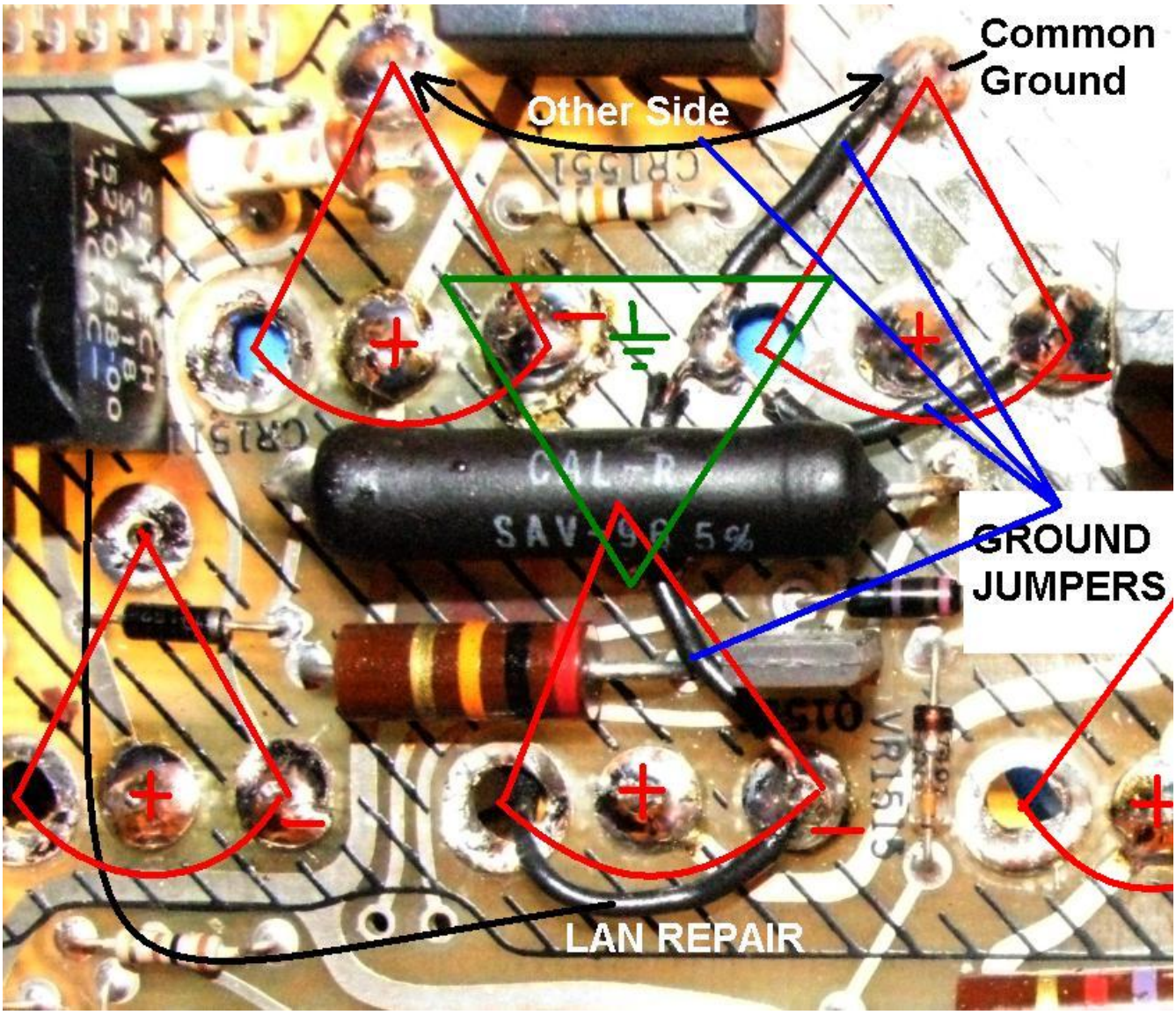

Figure 12: Adding Ground Jumpers

In Figure 12, notice the green triangle drawn in the center. This island pad acts as a central grounding location for original capacitors C1513, C1542 and C1552. Three ground jumpers are required to reconnect these three capacitors to the common chassis ground, shown in the upper right-hand corner. Also, an additional jumper is required to connect the negative (-) terminal of bridge rectifier CR1551 to the common ground. This jumper was added to the topside of the circuit board, as shown in the foreground of Figure 11

To repair circuit board damage incurred while removing C1513, a jumper was added from the negative (-) terminal of bridge rectifier CR1511 to the negative terminal of C1513. This jumper is shown at the bottom of Figure 12 with a black line drawn to show the final destination. This *Lan Repair* wire was routed through the unused ground pad hole and soldered to the underside of the bridge rectifier. This connection is visible and labeled *Lan Repair* in Figure 11. The original circuit trace landed on the larger ground pad of C1513. If undamaged, a jumper would have been required to the negative (-) terminal of C1513 or this capacitor could have been flipped 180 degrees to use the larger ground hole.

The bottom line is to be careful to restore all of the ground connections as indicated on the schematic, shown in Figure 2. Use an ohm meter to verify ground continuities. Pay special attention to C1512 and C1562 negative (-) terminals, which are NOT grounded. Check, double check, then check again...

Putting it Back Together

With the replacement capacitors installed, it's time to put everything back together. Reinstall *A8 Trigger Circuit Board* in the reverse direction. Solder the external, horizontal trigger connections and the *Trigger Hold-Off* switch. Plug in the ribbon cable connectors while observing polarity. And, finally plug in the three wires in front of the power supply capacitors to the bottom of the A8 board. Reconnect the power switch rod and insert the indicator light pipes.

Moment of Truth

Now, it is time for the smoke test. Plug in the scope, hold your breath and turn it on. Check the test points with a meter to verify proper voltages. If voltages read correctly, good job. Although not absolutely necessary, calibrating the scope is a good idea.

Taste of Success

Figure 13 shows the new capacitors installed. Double-side adhesive foam tape was used to secure C1513 and C1562 to the case. These capacitors are light weight, so the foam tape does a good job securing them for a quiet, sedentary life on the beach.. It's not a very pretty solution, but the job is done.

Removing the old capacitors was more difficult then anticipated. Pulling wisdom teeth is a good analogy. A more careful selection of replacement capacitors C1513 and C1562 would have enabled direct mounting to the circuit board without resorting to innovative alternatives.

More importantly, the symptom shown in Figure 1 is gone. The power supply is stable and hopefully good for another thirty years.

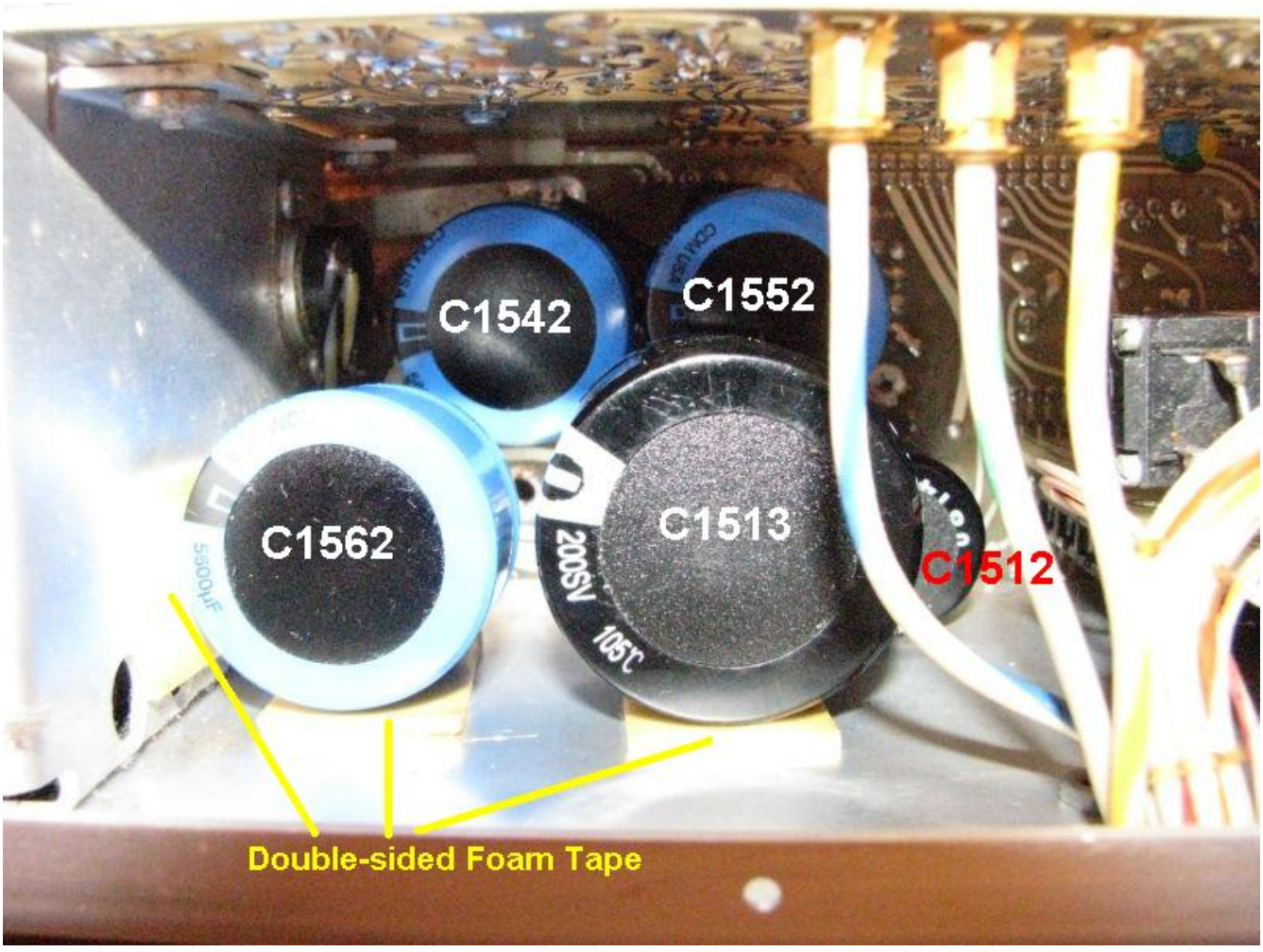

Figure 13: Newly installed Capacitors